Removal of the cyanobacterial toxin microcystin-LR by biofiltration

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Introduction

The occurrence and persistence of the cyanobacterial toxin, microcystin-LR, in natural waters has been reported worldwide, and its risk to public health and animals has been associated with water consumption. The effects of this toxin on humans and animals include total failure of respiratory system, hepatocyte necrosis and tumor promotion in the liver. Conventional water treatment processes such as coagulation, flocculation and filtration, have failed to remove algal toxins to recommended levels required by the World Health Organization (WHO). However, there has been reported effective biological degradation of microcystin-LR in field and laboratory studies using water samples from lakes where cyanobacterial blooms have historically occurred.

Hypothesis

Given that biological degradation of microcystin-LR is very effective, and that filters in water treatment plants can successfully remove naturally organic matter (NOM) via biofiltration, it is expected that microcystin-LR can be degraded by biologically active filters. Biological filters are established in water treatment plants when ozonation is introduced as a disinfectant. Following the approval by the US Environmental Protection Agency legislation to reduce Disinfection By-Products (DBP's) in potable waters, biological filters have become an important water treatment unit to meet the newly established DBP's standards.

Methods

Bench-scale microcystin biodegradation tests were carried out using an enrichment bacterial culture from Lake Mead, Nevada. Three bioreactors were incubated at room temperature for 7 days in the dark to avoid phototrophic growth. In each reactor containing 100 ml of Errington & Powell's medium, 32 mg/L of microcistin-LR was added. In order to evaluate the biodegradability of microcystin in the presence of different amounts of carbon, the amounts of glucose, citric acid, L-glutamic acid and succinic acid from the aforementioned medium were varied to obtain bioreactors containing 100%, 50 % and 0% additional carbon. Sub-samples from the reactors were taken daily for microcystin analysis and evaluation of its degradation rates.

The microcystin-degrading enrichment culture was then used to inoculate two bench-scale biofilters operating with typical design parameters of a drinking water treatment facility. The filters were packed with variable amounts of silica sand (effective size 0.51 mm) and anthracite (effective size 0.9 mm) to provide different empty bed contact times (EBCT). After a biofilm was established on the surface of the filter media, the filters were fed in continuous mode at hydraulic loading rate of 2.5 m/h. Dechlorinated tap water containing readily biodegradable organic matter (i.e. acetate and formate), bentonite and the toxin were added tothe filters. Acetate and formate are typical by-products of the ozonation of natural organic matter (NOM) and they are present in the influent water to the filtration units. Bentonite was used to simulate the particulate matter in surface water. Microcystin-LR concentrations varying from 10-130 g/L were added in the influent water. This range corresponds to dissolved microcystin-LR levels detected in lake waters during algal blooms. The concentration of microcystin-LR in the effluent was monitored every 12 hours and determined by Enzyme Linked Immunosorbent Assay (ELISA).

Results

The results of the biodegradation tests revealed a reduction of approximately 67% in the bioreactor to which no additional carbon source was added. Lower reductions were obtained in the experiments with carbon source addition. Therefore, it appears that microcystin itself can be used as a carbon source by the enrichment bacterial culture. These results are encouraging because concentrations of acetate and formate, byproducts of NOM ozonation, in drinking waters are low. Therefore, the potential to remove microcystin via biofiltration is high.